Chapter

# Chemical, Mineralogical, and Rheological Characterization of Regional Clays for Potential Use in Cosmetics and Pharmaceutical Products

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## Abstract

Four clay samples from different deposits in the state of Sergipe, Brazil, were fractionated by dispersion and centrifugation for comparative tests with a standard commercial clay used for cosmetic and pharmaceutical purposes. For this, they were characterized by X-ray diffraction, X-ray fluorescence spectroscopy, measurements of cation exchange capacity, oil absorption and viscosity, in addition to particle sizes and plasticity indexes. The objective was to determine the physical and chemical properties of raw clays and the consequent granulometric fractions to evaluate their potential use in products with high added value. After fractionation, the samples showed significant amounts of smectite and kaolinite, which combined with the size, particle distribution, chemical composition, and high adsorption capacity, especially in the PDL and PV samples, make them potentially interesting for applications in pharmaceutical and cosmetic products, they can also be used in spas and esthetic centers for therapeutic purposes based on their softness and cation exchange capacity.

**Keywords:** clay, clay minerals, ceramics, cosmetics, pharmaceutical use

## 1. Introduction

Clays have been used as raw material by humanity since antiquity for the manufacture of ceramic objects such as vases, bricks, and tiles and, more recently, in several technological applications, such as paper, paint, in the oil industry, adsorbents in lightening processes in the textile and food industry, catalysis etc., and their applications are strongly dependent on their structure, composition and physical properties [1, 2] (**Figure 1**).

The interest in its use has been gaining strength due to the search for environmentally friendly materials, that do not harm the environment when discarded, the abundance of world reserves and its low cost [3]. The possibility of chemical modification of clays allows the development of its use for different types of technological applications, adding value to this abundant natural resource. Raw clay deposits are rarely pure and most are composed of two or more clay minerals thoroughly

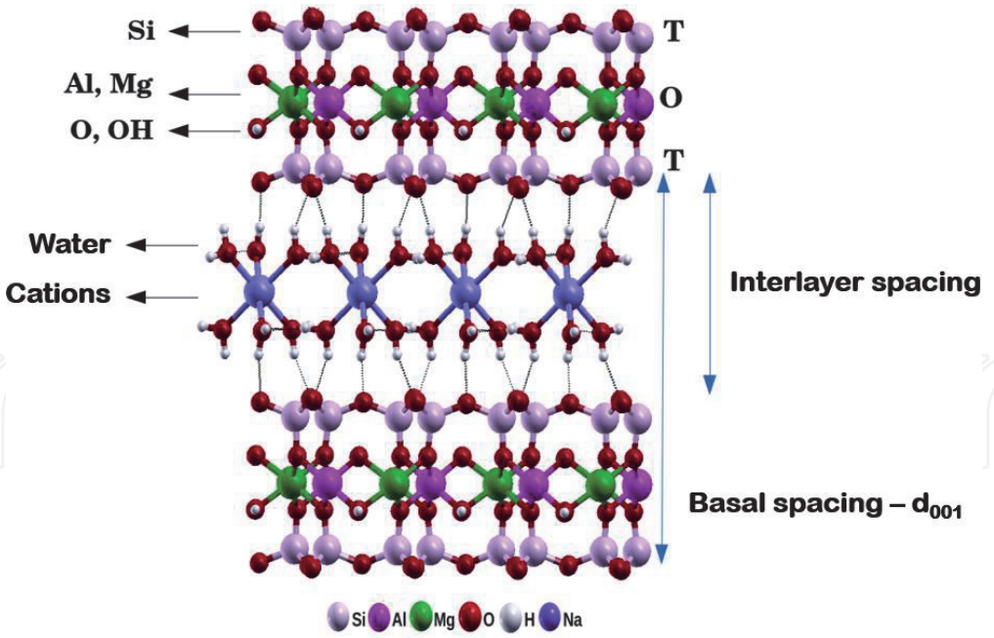


**Figure 1.**
*Typical representation of the structure of a clay.*

mixed with one another, and variable amounts of non-clay minerals in the form of associated minerals, amorphous materials, and organic matter [4–7].

Brazil is one of the main world suppliers of clay, and in the state of Sergipe, several clay deposits have been used for decades in the production of ceramic tiles, bricks, blocks, and handmade pieces [8–11]. However, these traditional products have low added value when compared to others, such as pharmaceuticals and cosmetics that use special clays in their composition. Among these clays, the most used industrially and commercially, is bentonite, a plastic clay from the group of smectites with a high content of colloidal matter, which can present varied colors, such as white, gray, yellow and others, depending on its origin and chemical composition [12]. According to [7, 13, 14], the industrial use of a clay in a pharmaceutical and cosmetic industry, is a consequence of the nature and properties of the clay that is an essential component of this clay, as well as its exchangeable cations. The ability of clays to exchange cations between interlayer spacing is a unique property and cationic exchanges with drugs are of special interest in pharmaceutical sciences, due to the interaction between drug-clay modifying the action of the drug in several ways, such as increasing stability, prolonged release, or increased dissolution [15].

Due to its high swelling power, which can reach up to twenty times its volume when immersed in water [16], bentonite is widely used as a pharmaceutical excipient, as a disintegrating agent in solid forms or to increase viscosity in liquid formulations [17]. As their layers form a kind of sandwich (phyllosilicates) can be seen in **Figure 2**, this characteristic allows them to absorb important amounts of water-soluble and fat-soluble substances, behaving in this way as cosmetic assets, the main differences being in the structure of the layers and metals (Fe, Zn, Cu, Mg etc.) that form each one [16].

In general, in Brazil, these segments use imported clays, because either there are no similar national products with the same degree of purity or the suppliers here are unable to maintain the pattern from one batch to the next. The aim of this work is to evaluate the potential use of four raw materials from different deposits of clays in the state of Sergipe, Brazil, after fractionation of the raw clay with the purpose of knowing its physical and chemical characteristics aiming at the possibility of use in products of high added value by the pharmaceutical and cosmetics industry. The

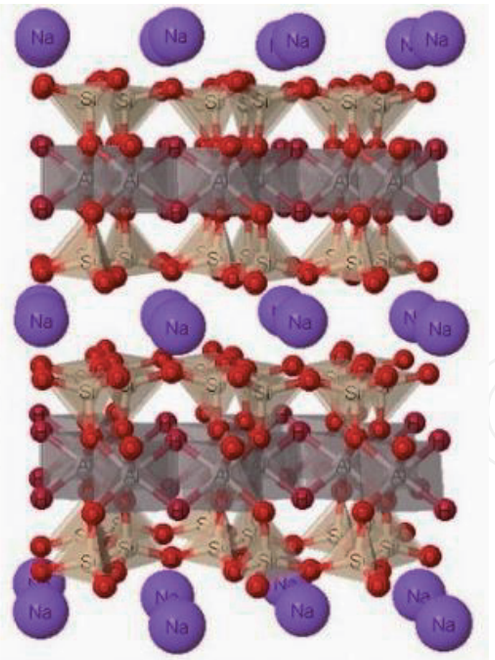


**Figure 2.**
*Typical representation of the montmorillonite structure.*

synthesis and study of clays and clay minerals are one of the widest fields of research in materials science and technology.

## 2. Materials and methods

The clays investigated in this work come from deposits known as Ventinha (VEN), Poço Verde (PV), Pau-de-leite (PDL) and Pinheiro (PIN), all located in the state of Sergipe, Brazil. Currently, these clay deposits are used in the production of ceramic tiles, as reported by [8–11], in addition to other traditional applications, such as bricks, blocks, tiles and handmade pieces. A sample of commercial bentonite clay from the Bentec brand (BEN) used in the pharmaceutical and cosmetics industry was used as a standard.

Initially, the raw materials from the clay deposits were placed in trays and air-dried for 72 h to be mechanically treated to break up the particles, being quartered, broken up and ground in a hammer mill with a 2 mm opening grid for homogenization, and dried at 60°C for 24 h. The fractionation of the raw clay was carried out by dispersion and centrifugation, according to [7], in which 30 g of dry clay were added to a metallic vessel containing 300 ml of distilled water, then the dispersion was stirred at 14000 rpm for 20 min, being then transferred to a 600 ml beaker and left to stand overnight at room temperature. After the resting time, the dispersion was again stirred, centrifuged at 1500 rpm for 15 min and the supernatant transferred to a container. At the end of the process, all samples were dried at 60°C for 24 h.

To determine the particle size distribution curves, the samples passed through a 297 μm aperture sieve. The technique used was Low Angle Laser Light Scattering (LALLS), according to the Fraunhofer diffraction method [18] in a Malvern equipment model Mastersizer MS2000E with dispersing agent, at 2000 rpm and ultrasound speed equal to 11. The light source is a He-Ne laser with a wavelength of 632.8 nm and the reliable particle size measurement range is 0.1 μm to 1000 μm.

To assess plasticity, liquidity, and plasticity limits (LL and PL) were measured according to the procedures of ASTM D4318:2010 [19], NBR 7180:1984 [20] and

NBR 6459:2016 [21]. The plasticity index (PI) is obtained from the arithmetic difference between the liquidity and plasticity limits.

X-ray fluorescence (XRF) analyzes determined the chemical compositions of the samples with a mass of 10.0 g pressed in a cylindrical shape with a diameter of 40.0 mm and a thickness of 4.0 mm kept in a vacuum of $10^{-6}$ bar. The equipment used was a Bruker model S8 Tiger, in which the percentages of constituent oxides were estimated using the semi-quantitative method. A mixture of 90% argon and 10% methane (P-10) was used in the proportional counter.

The crystalline phases present in the clays were determined by X-ray diffraction (XRD) in a Bruker D8 Advance equipment using $CuK_{\alpha 1}$ radiation ($\lambda$ = 1.5418 Å) of the dry non-oriented powder in the continuous scanning mode in the range from 1° to 65° with increment of 0.02° and capture time of 0.4 s/step. To confirm the presence of montmorillonite, which is a clay mineral of the group of smectites with a potentially unstable laminar structure formed by stacking layers composed of an octahedral leaf interspersed with two tetrahedral leaves, the samples were saturated with ethylene glycol for 1 h, to induce increasing the interplanar distance. In this case, the scanning interval was between 1° and 15° [22]. The samples were calcined at 550°C for 2 h and the XRD analyzes were compared with the dry and glycolated samples. Analyzes were also carried out on samples oriented after fractionation of the raw clay, separated by centrifugation, and washed with $H_2O_2$ to eliminate organic matter and HCl to eliminate carbonates, according to [23]. The diffraction patterns were indexed using the Inorganic Crystal Structure Database (ICSD), according to the standard method based on the shape, position, and intensity of specific reflections.

The values of cation exchange capacity (CEC) of the clay fraction of the samples were determined according to ASTM-C837–09:2019 (Standard Test Method for Methylene Blue Index of Clay) [24].

The oil absorption of the clay fraction was determined according to ASTM D281–12:2016 [25], with 10 g of each sample placed on a glass plate and a drop of mineral oil was applied from a container previously weighed to the clay, being incorporated with the help of a spatula. The test is considered complete when, by sliding the spatula on the upper surface of the treated mass, a thin layer of oil is observed. The oil container was then weighed again to calculate the percentage of oil incorporated.

The rheological properties of the clay fraction were determined by a TA Instrument model DHR 10 rheometer, of the cone/geometric plate type with 50 mm spacing, with the stainless-steel cone having a diameter of 60 mm and an angle of 2°. The formulations were analyzed at (25.0 ± 1.0) °C. Each sample was applied to the lower plate, ensuring minimum shear, and allowing a rest time of 1 min before each removal. Each run lasted 4 min and was carried out with a shear speed from 0 to 200 $s^{-1}$. The data were adjusted using the Ostwald-de Waele model or Power Low model. For this, clay-water dispersions were prepared with a concentration of 4.86% by mass: 24.3 g of clay added to 500 ml of deionized water. The mixture was stirred for 20 min at 17000 rpm and left to stand for 24 h. After that time, the material was stirred for 5 min at 17000 rpm and the respective viscosities were determined.

## 3. Characterization of materials and results

The particle size distribution curves of the five clays studied after passing through a 297 μm sieve through laser light diffraction can be seen in **Figure 3**, in which an approximately Gaussian profile can be seen in all curves, the which confirms a multimodal distribution of the particles [26].

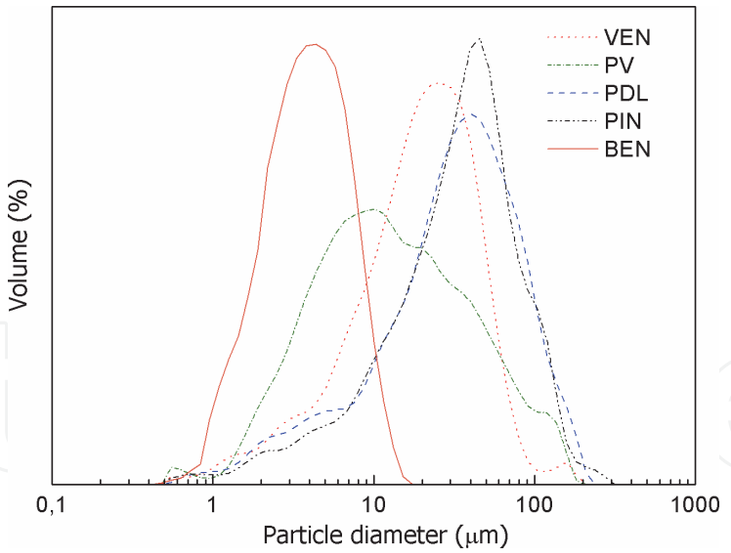


**Figure 3.**
*Particle size distribution of samples by laser light diffraction.*

According to ABNT NBR 6502:1995 [27], the particle size classification is: clay fraction (< 2 μm), silt fraction (2–20 μm) and sand fraction (> 20 μm), being that the proportion of particles with a diameter less than 2 μm is associated with the presence of clay minerals and is a determining factor for the plasticity and smoothness of the material. As expected, commercial bentonite clay (BEN) was the one with the highest proportion of particles with smaller dimensions, followed by PV and VEN.

**Table 1** presents the results of the particle sizes and the Atterberg limits of the samples. Among the raw materials, PV was the one with the highest proportion of particles smaller than 2 μm, known as the clay fraction. It also showed the highest index of plasticity, which confirms the dependence between PI and the clay fraction, previously reported by [28]. Materials with PI between 1 and 7% are considered weakly plastic, from 7 to 15% are moderately plastic and above 15%, highly plastic [29]. According to this classification, the PI values determined for VEN, PV and PDL indicate that these clays are highly plastic, while PIN is moderately plastic (PI = 14%). The smoothness, linked to the small size of the particles, is important for therapeutic and cosmetic purposes of the skin, such as facial mask and body clay creams [30]. In this way, VEN, PV and PDL clays can be used for this purpose. Comparing the average diameter of the particles, PV (7.2 μm) stands out from the other clays and slightly approaches the value found in BEN (6.7 μm).

**Table 2** shows the chemical compositions of the samples determined by XRF. The results show that they all contain considerable amounts of $SiO_2$ and $Al_2O_3$.

| Samples | Particle size (%) | | | | Atterberg limits (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | < 2 (μm) | 2–20 (μm) | 20–200 (μm) | > 200 (μm) | $d_m$ (μm) | LL | PL | PI |
| VEN | 5.25 | 46.08 | 48.67 | — | 23.7 | 48 | 21 | 27 |
| PV | 14.23 | 61.44 | 24.33 | — | 7.2 | 56 | 24 | 32 |
| PDL | 6.67 | 44.38 | 48.95 | — | 21.1 | 51 | 27 | 24 |
| PIN | 4.81 | 44.69 | 50.50 | — | 28.3 | 37 | 23 | 14 |
| BEN | 48.17 | 51.83 | — | — | 6.7 | 69 | 25 | 44 |

**Table 1.**
*Size distribution, average particle diameter and Atterberg limits of the samples.*

These elements are associated with the tetrahedral sheet of silica and the octahedral sheet of alumina, the basic units that can form the structure of smectite and kaolinite, as well as Mg, K, Ca, Na and Fe, are associated with structures of clay minerals, quartz, and feldspars [31–33]. The high content of calcium oxide in PIN and VEN characterizes these clays as limestone [11, 34], but combined with $Na_2O$ and $K_2O$ it can be associated with the cations of the smectites interstitial space, usually $Ca^{2+}$, $Na^{+}$, $K^{+}$ and $Mg^{2+}$, which balances the negative charge of the 2:1 layer of the isomorphic substitution in the crystalline structure [7]. The high amounts of $Fe_2O_3$ and MgO may be related to the isomorphic substitutions of $Al^{3+}$ for $Fe^{3+}$, $Fe^{2+}$ and $Mg^{2+}$ in the octahedral leaves of smectite [16]. All samples have small amounts of $TiO_2$ (< 0.8%). The chemical composition of the commercial bentonite studied is in accordance with other works reported [35, 36].

The X-ray diffraction patterns of the dry non-oriented powder of the clays (bulk composition) are presented in **Figure 4** and correlate positively with the results observed by X-ray fluorescence. The crystalline phases were identified according to the Inorganic Crystal Structure Database (ICSD).

| Oxides | VEN | PV | PDL | PIN | BEN |
|---|---|---|---|---|---|
| $SiO_2$ | 51.31 | 53.17 | 61.74 | 47.43 | 57.51 |
| $Al_2O_3$ | 16.36 | 18.84 | 17.94 | 14.72 | 21.80 |
| $Fe_2O_3$ | 6.07 | 6.81 | 4.22 | 7.04 | 6.11 |
| CaO | 6.81 | 2.08 | 0.88 | 11.93 | 3.23 |
| $K_2O$ | 3.06 | 4.35 | 3.62 | 3.25 | 1.68 |
| $Na_2O$ | 0.47 | 0.41 | 0.58 | 0.67 | 0.47 |
| MgO | 2.24 | 2.28 | 1.47 | 2.26 | 3.23 |
| $TiO_2$ | 0.68 | 0.83 | 0.59 | 0.77 | 1.07 |
| LOI | 11.9 | 14.1 | 8.4 | 12.2 | 6.1 |

**Table 2.**
*Chemical composition (main components, oxide form) of the samples from X-ray fluorescence analyses, indicated in mass %.*

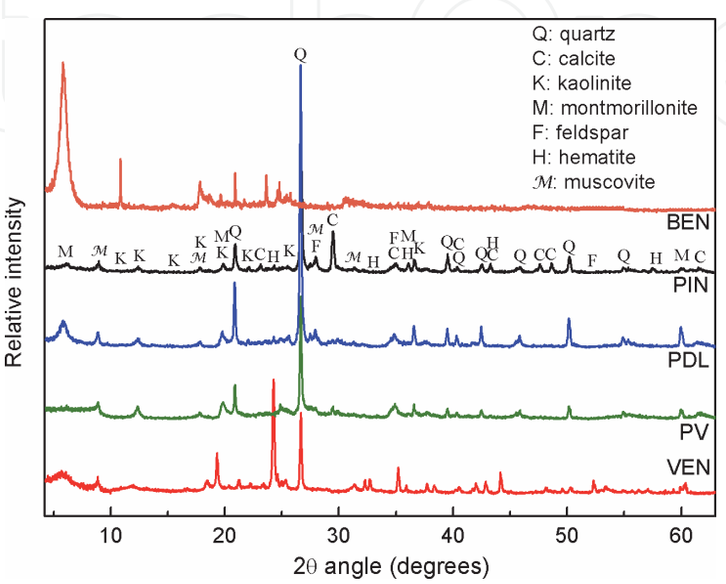


**Figure 4.**
*X-ray diffraction patterns of the clays studied.*

Regional clays are predominantly composed of quartz, followed by muscovite, kaolinite, montmorillonite, calcite, feldspar, and hematite (**Table 3**). The PDL sample presents the highest proportions of the clay minerals montmorillonite and kaolinite, followed by PV. These clay minerals are widely used in cosmetic products, such as creams, powders and emulsions, and pharmaceutical products, including gastrointestinal and dermatological protectors, anti-diarrheal and anti-inflammatory [36]. The calcite percentage varied considerably between the studied samples, with extremes of 1.31% (PDL) and 13.44% (PIN). This mineral has a high acid absorption capacity. The addition of HCl to calcite in a neutralization reaction gives rise to calcium chloride, releasing $CO_2$. Clay minerals can neutralize acidity by adsorbing $H^+$ ions from the external environment, properties that are useful in the pharmaceutical industry [13]. The BEN sample is composed mainly of montmorillonite and kaolinite and small amounts of quartz and hematite.

All samples from regional deposits are homogeneous in color, with PDL being the lightest, followed by PV, probably due to the greater amount of clay minerals and the small presence of hematite, while VEN has a reddish color. The color of clays is a very important parameter in cosmetic applications. Commercially, color is often associated with the purity and quality of clays, however, studies that attest to these properties are necessary [37].

To confirm the presence of montmorillonite by increasing the spacing between its structural layers due to the absorption of water or alcohol molecules, the diffraction pattern of the samples saturated with ethylene glycol was measured [38, 39]. In all samples, the typical expandable property of smectite was obvious, by increasing the interplanar distance related to the direction (001) and the consequent displacement of the diffraction peaks to smaller angles in relation to the dry sample tests [40]. Smectites are widely used in pharmaceutical products because they favor the release of the active ingredient because their particles can swell in water and decompose readily in the acidic environment of the stomach (pH $\sim$ 2) [14].

The X-ray diffraction patterns of the dried PDL sample and treated with ethylene glycol can be seen in **Figure 5**, in which we notice that the angle relative to the direction (001) of the glycolated sample has shifted to a smaller angle. According to Bragg's Law ($n\lambda = 2dsen\theta$), this reduction is caused by the increase in interplanar distance and these values can be calculated. The presence of montmorillonite in the PDL sample was confirmed by the displacement from 5.76° (d = 15.36 Å) to 5.31° (d = 16.66 Å) and in PV the interplanar distance that was 15.34 Å increased to 17.12 Å. In the VEN sample from 15.17 Å to 17.03 Å and from 13.95 Å to 15.88 Å in PIN.

**Figure 6** shows the X-ray diffraction patterns of the samples in the region where there is a reflection close to 1.50 Å (61.72°), corresponding to the plane (060), indicating that they are dioctahedral smectites [41], probably a dioctahedral component

| Minerals (%) | VEN | PV | PDL | PIN | BEN |
|---|---|---|---|---|---|
| Quartz | 56.36 | 53.54 | 59.08 | 56.11 | 6.11 |
| Kaolinite | 6.86 | 13.08 | 9.21 | 5.95 | 17.69 |
| Muscovite | 9.11 | 10.74 | 11.48 | 12.03 | 1.12 |
| Montmorillonite | 6.21 | 4.49 | 9.84 | 4.96 | 69.12 |
| Calcite | 8.08 | 2.92 | 1.31 | 13.44 | 0.78 |
| Feldspar | 6.00 | 9.54 | 5.86 | 3.95 | 0.57 |
| Hematite | 5.61 | 5.02 | 2.79 | 1.97 | 3.12 |

**Table 3.**
*Mineralogical compositions of samples determined by X-ray diffraction.*

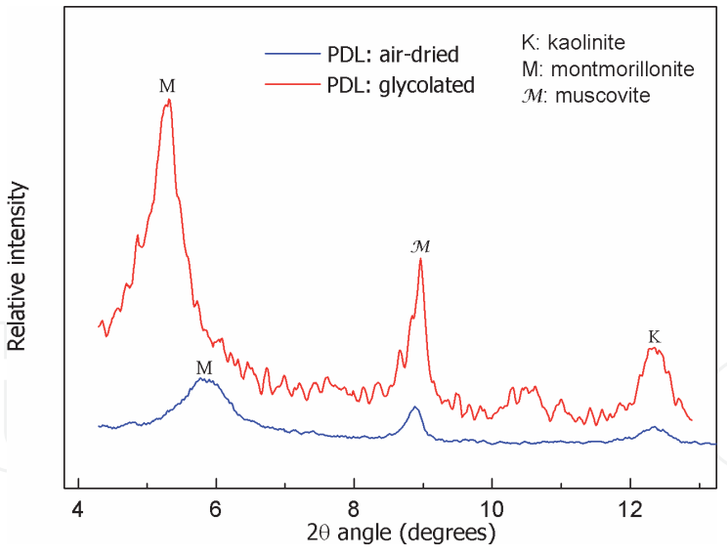


**Figure 5.**
*X-ray diffraction patterns of the sample PDL after air-drying and glycolated.*

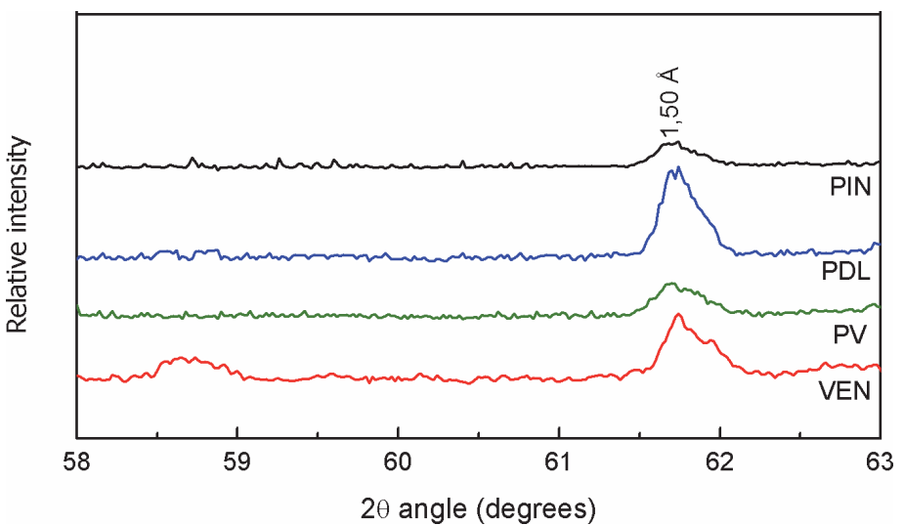


**Figure 6.**
*X-ray diffraction patterns of non-oriented samples showing 060 peaks of the clays.*

Fe-rich [42, 43], due to the chemical and mineralogical compositions observed in these samples. In addition, they have a very weak reflection at 1.54 Å, indicating small presence of trioctahedral smectite components, Fe-rich and Mg-rich [7, 23].

**Figure 7** shows the X-ray diffraction curves of VEN, PV, PDL and PIN after heat treatment at 550°C. The air-dried samples show an intense reflection due to an interplanar spacing $d_{001}$ of approximately 5.76° and 12.28° (**Figure 4**), corresponding to the reflections (001) of montmorillonite and kaolinite, respectively [44]. However, after heating, the characteristic collapse of these two clay minerals is observed. These changes are consistent with smectites and indicate that the samples do not reflect due to any other clay minerals, such as chlorites or vermiculites [7, 45]. The reflection in 8.83° (10.04 Å), which was not affected by chemical treatment or heating, indicated the presence of illite/muscovite [30].

The mineralogical compositions of the clay fractions were carried out after the fractionation of raw clay by dispersion and centrifugation. In terms of bulk composition, all samples are characterized by the presence of a significant non-clayey fraction represented by quartz, calcite, feldspar, and hematite, as well as considerable portions of clay minerals (**Table 3**). However, for use in pharmaceuticals and

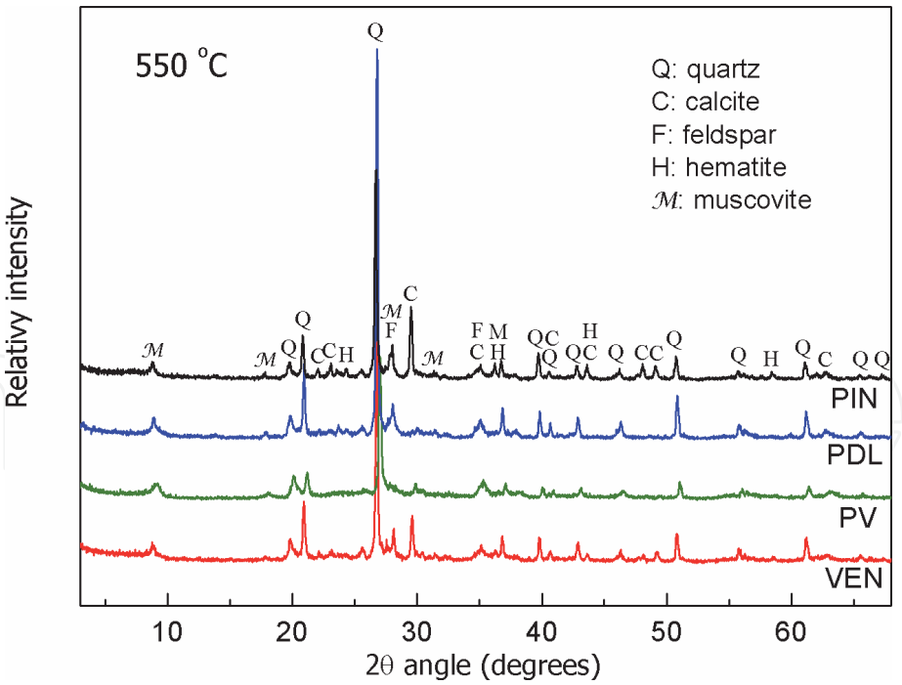


**Figure 7.**
*Resulting phases after heat treatment at 550°C of the samples.*

cosmetics, these impurities must be suppressed [3]. Montmorillonites with a high degree of purity have application in a wide variety of areas such as selective adsorbents, medicaments, membranes, production of organophilic clays, catalysts, among others [46], and should contain levels like the sample used as standard in this work (~70% montmorillonite, ~17% kaolinite).

The results of XRD after beneficiation (**Figure 8**) indicate that PDL is composed of 62% montmorillonite and 22% kaolinite, while PV has 55% montmorillonite and 28% kaolinite, both without the presence of Si-polymorphs (α-quartz or cristobalite). These results are consistent with the mineralogical compositions reported in the literature for commercial clays used in pharmaceuticals and cosmetics [30]. VEN (52% montmorillonite, 19% kaolinite) and PIN (47% montmorillonite, 16% kaolinite) are made up of smaller quantities of these clay minerals, with traces of hematite (VEN), calcite and muscovite (PIN).

The values of the cation exchange capacity (CEC) of the samples after centrifugation show significant differences, the highest being in PDL (92.5 meq/100 g) and PV (78.9 meq/100 g) due to the higher smectite content in these samples, because the CEC values of smectites (80–160 meq/100 g) are higher than those of kaolinite (4–20 meq/100 g) [13]. VEN showed a value of 70.7 meq/100 g and PIN 63.4 meq/100 g. The standard sample (BEN) presented the highest value among the five studied samples (118.2 meq/100 g).

The oil absorption capacity of the clays was expressive for the PDL (43%, w/v) and PV (41%, w/v) samples, approaching the BEN standard sample (48%, w/v). The oil absorption value obtained by this test method gives information about the vehicle demand of the fluid, evidencing possible use of these samples in applications that require high adsorption capacity, such as creams, powders, and emulsions [7]. VEN and PIN obtained the results of 30 and 23 (%, w/v), respectively.

The correlation between the strain gradient (shear stress) as directly proportional to the applied force (shear rate) defines the rheological behavior of a fluid [47]. Newtonian fluids follow Newton's law, showing a proportionality relationship between the rate and shear stress, resulting in constant viscosity$(\eta = \tan\alpha)$. The model used in this work was Ostwald-de Waele (or Power Law) [48], according to

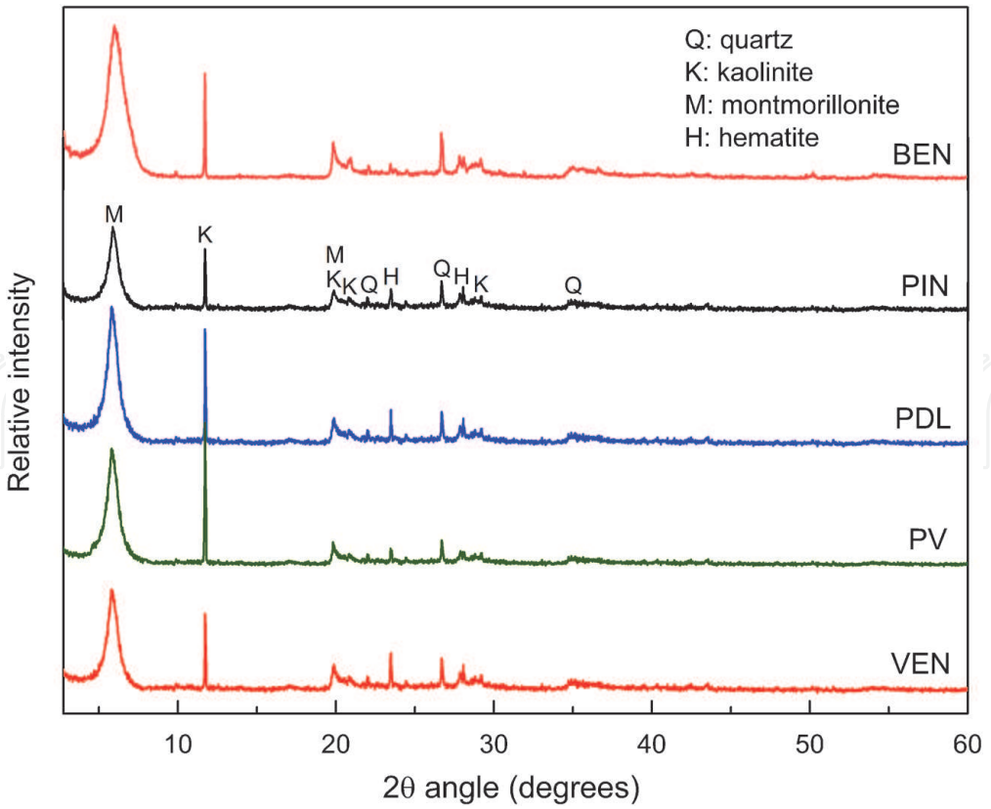


**Figure 8.**
*X-ray diffraction patterns of the investigated samples (clay fraction).*

Eq. (1), where η is the viscosity (Pa.s), $\dot{\gamma}$ corresponds to the shear stress (Pa) and $\dot{\gamma}$ is the shear rate ($s^{-1}$) [49]:

$$\sigma = n.\dot{\gamma} \tag{1}$$

In non-Newtonian fluids, this proportionality relationship does not exist and the viscosity is altered as a function of the shear rate. The evaluation of parameter η of Eq. (2) defines the behavior of the fluid in Newtonian or non-Newtonian. When $\eta = 1$ the system is considered Newtonian, $\eta < 1$ pseudoplastic and $\eta > 1$ dilating.

$$\sigma = K.\gamma^{n} \tag{2}$$

The reogram of the samples can be seen in **Figure 9** where the shear stress is a function of the shear rate. According to the rheological parameters presented in **Table 4** determined using the Ostwald-de Waele model, all samples have a linear correlation between the rate and shear stress, maintaining the constant viscosity typical of Newtonian behavior ($\eta = 1$) presenting values of $R^2 \geq 0.99991$, indicating an excellent correlation between experimental and theoretical data [49].

The viscosity of the material directly assists in the interpretation of the release tests, since the speed of diffusion of a drug with its consequent final release to the receiving middle, also depends on the barrier imposed by the viscosity of the system, which can facilitate or hinder the fraction of drug available per unit time [50]. By dispersing clay mineral particles in the water, the viscosity of the medium (water) is greatly increased. Thus, smectites can be used as a diluent in pharmaceutical and cosmetic preparations, as they are plastic when wet and particularly useful as stabilizers due to their thixotropic properties, and due to their large specific surface area and high adsorption capacity, they are suitable for act as carriers and releasers of drugs [13].

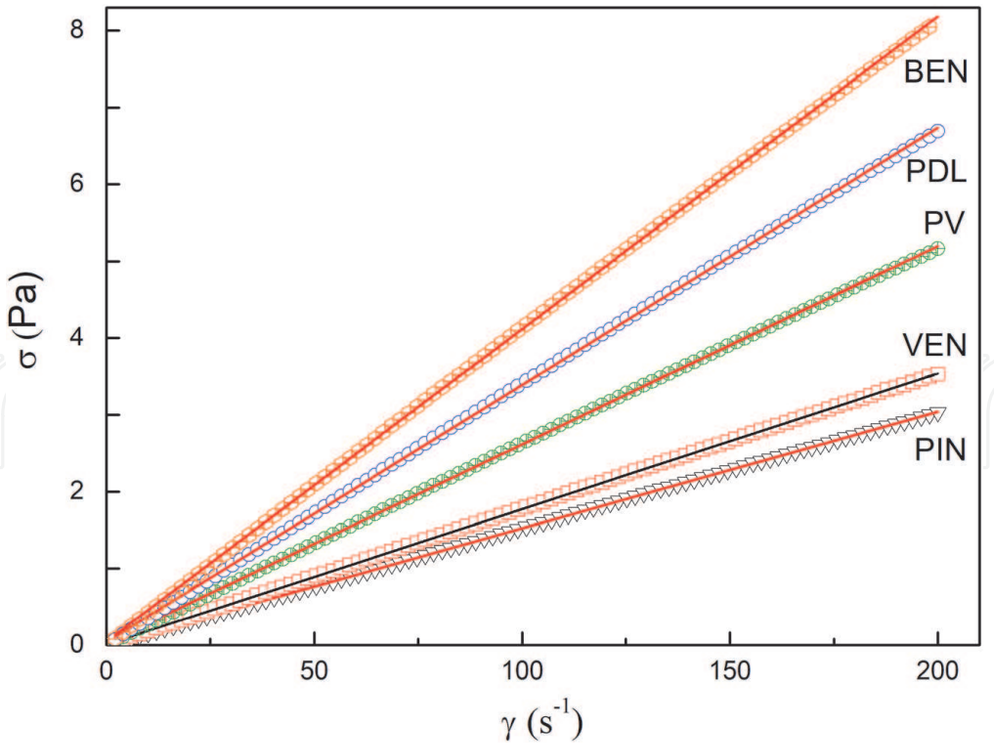


**Figure 9.**
*Reogram of the investigated samples showing their Newtonian behavior.*

| Sample | Flow parameters | |
|---|---|---|
| | $\eta$ (Pa.s) | $R^2$ |
| VEN | 0.01743 | 0.99998 |
| PV | 0.02552 | 0.99993 |
| PDL | 0.03307 | 0.99991 |
| PIN | 0.01515 | 0.99998 |
| BEN | 0.04068 | 0.99991 |

**Table 4.**
*Viscosity values (η) and the correlation coefficient ($R^2$) of the samples.*

The viscosity values of the PDL and PV clays, together with the size, particle distribution and quantity of clay minerals, make them suitable for the applications mentioned, as well as providing stability in emulsions and can be used in spas and esthetic centers for therapeutic purposes based on its smoothness, rheological properties, high water adsorption capacity and cation exchange, after mixing with natural water [51].

According to [52, 53], VEN and PIN can be used as drilling fluids for oil wells, as they have values above 15 cP (0.015 Pa.s), in accordance with the standard EP-1EP-00011-A [54]. For drugs and cosmetics, these samples have low values of η, probably due to the lower amount of clay minerals combined with impurities, such as quartz, calcite, and hematite.

## 4. Conclusions and outlook

We describe the chemical, mineralogical and rheological characterization of samples from four clay deposits before and after fractionation of the raw clays that

are used in the production of ceramic tiles, bricks, blocks and artisanal pieces in the state of Sergipe, Brazil, for possible use in high value-added products, such as cosmetics and pharmaceuticals.

The PV sample showed the highest proportion of particles in the clay fraction, the smallest average particle diameter and the highest plasticity index among the raw samples. The chemical compositions show that they all contain considerable amounts of $SiO_2$ and $Al_2O_3$ and small amounts of $TiO_2$, with a high content of CaO in PIN and VEN.

PDL presents the highest proportions of montmorillonite and kaolinite, followed by PV. After heat treatment, the characteristic collapse of these clay minerals was observed, indicating that there is no reflection due to any other clay mineral, such as chlorites or vermiculites. The mineralogical compositions after fractionation showed the majority presence of clay minerals, with PDL composed of 62% montmorillonite and 22% kaolinite, while PV has 55% montmorillonite and 28% kaolinite, results consistent with reported in the literature for clays used in pharmaceutical products and cosmetics. However, VEN and PIN are made up of smaller quantities of these clay minerals, with traces of hematite (VEN), calcite and muscovite (PIN).

The values of cation exchange capacity after centrifugation show differences, being higher in PDL and PV due to the higher smectite content by them. The oil adsorption capacity was expressive in PDL and PV, approaching the standard sample used in this work, showing possible applications that require high adsorption capacity, such as creams, powders and emulsions.

The rheological parameters demonstrated an excellent linear correlation between the rate and shear stress, maintaining the constant viscosity typical of Newtonian behavior. These values in PDL and PV, combined with size, particle distribution, chemical composition, amount of clay minerals and high absorption capacity, show that they have the greatest potential for applications in cosmetics and drugs, as well as providing stability in emulsions and can be used in spas and esthetic centers for therapeutic purposes based on their softness and cation exchange capacity.

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